159097 NHTSA-2000-8011-20

LABORATORY TIRE STRENGTH TESTS- PHASE 1A

All Phase 1A laboratory tire strength tests were conducted at Standards Testing Lab (STL) in Massilon, Ohio, USA [1]. Strength Testing consisted of the original SAE J1981 Road Hazard Impact test [2], a modified SAE J1981 Road Hazard Impact test, the FMVSS 109/119 Tire Strength test, and a modified FMVSS 109/119 Tire Strength test. A total of sixty tires were tested and put through post-test visual inspection, shearography, and x-ray to determine the amount and extent of tire damage. Twenty of the tested tires were subjected to the current FMVSS 109/119 High Speed Performance test, and again visually inspected, shearographed, and x-rayed to check for further damages.

1.0 SAE J1981 ROAD HAZARD IMPACT TEST

The laboratory tire strength tests were modeled after the Society of Automotive Engineer's (SAE) J1981 Road Hazard Impact Test for Wheel and Tire Assemblies (Passenger Car, Light Truck, and Multipurpose Vehicles) procedure. This procedure was originally created to simulate wheel damage occurring with impacts to road obstructions such as potholes, curbs, etc. It was later recognized as a potential test for rim/tire system performance as well.

1.1 Test Equipment

The STL Road Hazard Impact machine [3] consists of a framework designed to guide the Pendulum Weight System which, when released, will free fall to impact with the tire/wheel assembly. The machine features a triple clutch brake system for lifting and releasing the pendulum. An electrically actuated disc brake system is utilized to limit the pendulum to a single impact. The machine was designed to meet SAE J1981 specifications, with options to change and adjust the striker, and to increase the drop mass. The machine settings used in Phase 1A laboratory tests were in accordance with SAE J1981 specifications as follows [2]:

Pendulum

Length .....1828.8 mm (6 feet), from pivot to striker.

Range of Travel.....From 0 degrees (arm vertical at lowest point) to 179 degrees (arm almost vertical at top of travel).

Drop Mass.....54 kg (120 lbs), at striker center of gravity.

Single Strike Device.....Magnetic break insures single impact to the tire with no rebound.

Striker Heads.....*i*)Nodular Cast Iron Wedge Striker (SAE J1981 Specified; Figure 1)

ii) *(Optional)* Plunger Striker - 2" diameter cylindrical steel plunger with hemispherical end (similar to plunger used in FMVSS 109/119 static plunger test, but larger diameter)

1.2 Test Procedure

Each SAE J1981 Road Hazard Impact Test was setup and conducted as follows (Figure 1 and Figure 2):

i. The desired striker was bolted to the end of the pendulum

ii. The test wheel was mounted to the wheel holding fixture so that the pendulum was just touching the tire while in the free-hanging position. The centerline of the tire rim was aligned with the centerline of the striker.

iii. The striker was raised to a predetermined drop height and released to free fall and impact the tire. A brake system limited the impact to one strike.

iv. The tire and rim were rotated about the wheel axis 90 degrees (Figure 3) and step (iii) was repeated.

v. Step (iii) was repeated once more.

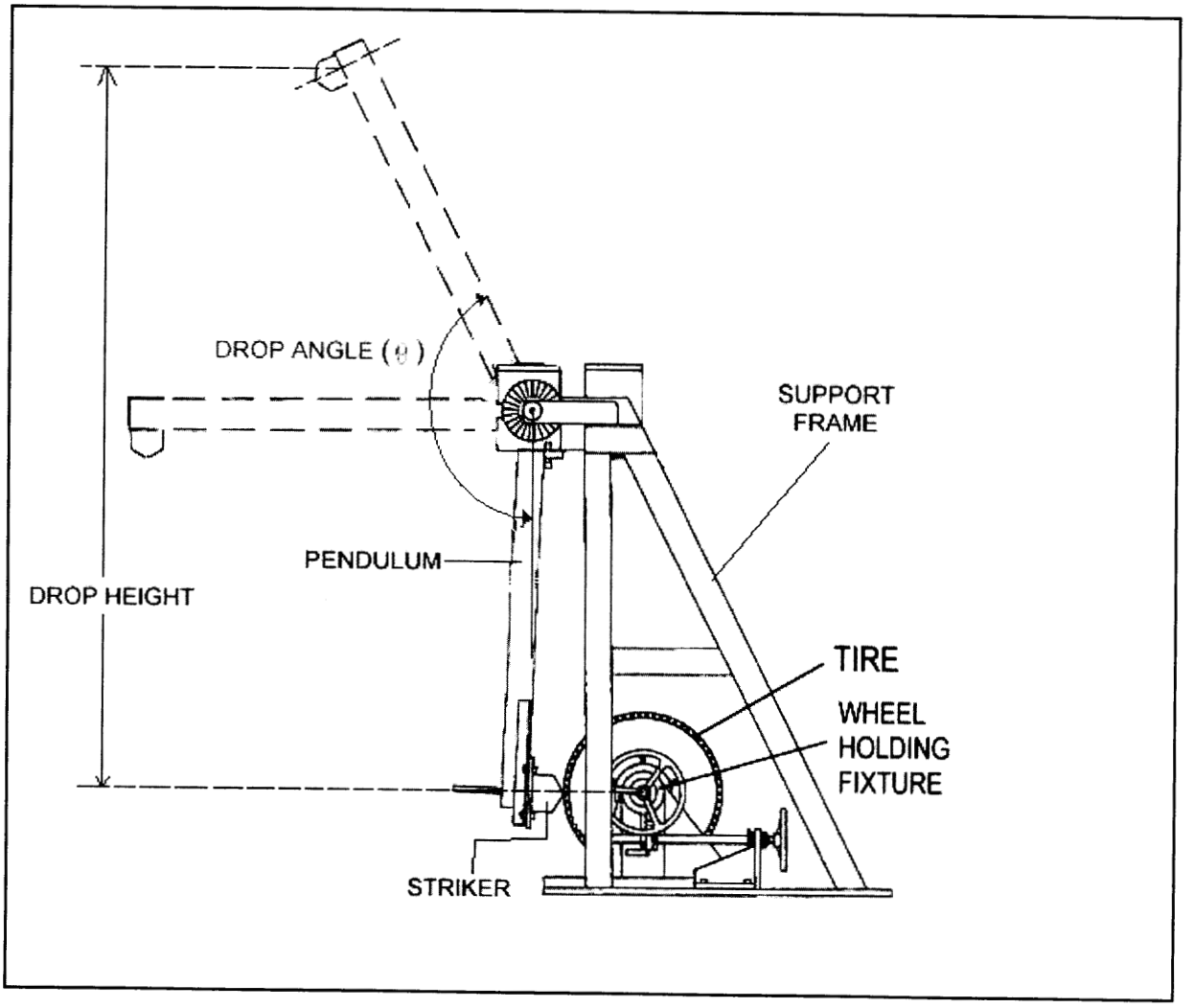

Figure 1: Frontal (radial) impact test machine (SAE J1981)

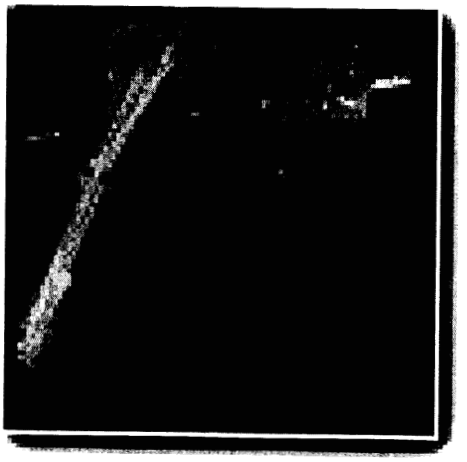

Figure 2: Radial impact test machine

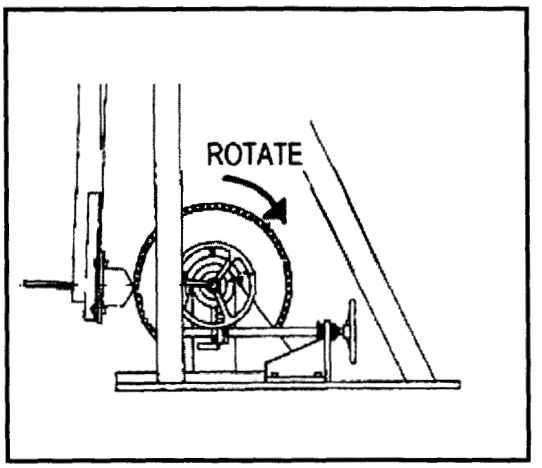

Figure 3: Tire rotation

1.3 Test Results

Table 1 summarizes the test results obtained from the SAE J1981 Road Hazard Impact Tests, using the (original/specified) wedge and (optional) plunger strikers. The drop angles were visually determined by test technicians, using markings on the test machine. The peak accelerations were measured by an accelerometer affixed to the pendulum behind the striker. Values for the peak forces were calculated using Newton's Second Law:

$$Force = Mass^{*} \times Acceleration,\ F = ma$$

** The effective mass of the striker used in these tests is 54 kg (120 lbs).*

Equation 1: Newton's Second Law

The cells marked with an "X" denote the occurrence of what is listed in the column heading. For example, if a cell is marked in the column headed "Rim Damage/Bend," then the rim was bent in that test.

The cells shaded gray denote the tires that were subjected to the current FMVSS 109/119 High Speed Test following strength testing (damage inspections were done first). The results of those tests will be discussed in Section 3.3.

Table 1: SAE J1981 Road Hazard Impact Test Results (Original/Wedge & Modified/Plunger)

Tested Tire Mfg/Brand/Size	Test Number	Pendulum Drop Angle (deg)	Peak Acceler-ation (g)	Peak Force (N)	Tire Damage/ Air Loss	Rim Contact/ Striker Bottom-Out	Rim Damage/ Bend	Striker: Wedge/ Plunger
Goodyear Eagle GT II; 205/55R15	[illegible]	60	17.88	9469				WEDGE IMPACTS
	[illegible]	80	42.13	22310				
	[illegible]	100	53.96	28575		X		
	NHS1-4A	60	17.23	9124				
	NHS1-4B	80	37.16	19678				
	NHS1-4C	100	55.54	29412		X		
Michelin Pilot HX; 205/55R15	[illegible]	60	17.73	9389				
	[illegible]	80	40.91	21664		X	X	
	[illegible]	100	51.66	27357		X	X	
	NHS1-8A	60	16.67	8828				
	NHS1-8B	80	34.98	18524				
	NHS1-8C	100	50.77	26886		X		
Michelin RF MX4; 205/65R15	[illegible]	60	16.05	8499				
	[illegible]	80	28.35	15013				
	[illegible]	100	53.5	28331		X		
	NHS1-40A	60	16.42	8695				
	NHS1-40B	80	23.44	12413				
	NHS1-40C	100	45.95	24333		X		
Goodyear Eagle GA; 205/65R15	[illegible]	60	16.49	8732				
	[illegible]	80	23.06	12212				
	[illegible]	100	53.97	28580		X		
	NHS1-46A	60	16.61	8796				
	NHS1-46B	80	26.54	14054				
	NHS1-46C	100	52.92	28024		X		
Firestone FT 70C; 205/65R15	[illegible]	60	14.84	7859				
	[illegible]	80	34.57	18307				
	[illegible]	100	52.79	27955		X	X	
	NHS1-52A	60	16.16	8558				
	NHS1-52B	80	25.62	13567				
	NHS1-52C	100	41.87	22173		X		
Dunlop SP Sport 4000; 205/65R15	[illegible]	60	16.53	8754				
	[illegible]	80	22.21	11762				
	[illegible]	100	42.27	22384		X		
	NHS1-58A	60	16	8473				
	NHS1-58B	80	25.64	13578				
	NHS1-58C	100	44.82	23735		X		

BF Goodrich TA TR4; 205/65R15	[illegible]	60	16.71	8849			
	[illegible]	80	27.37	14494			
	[illegible]	100	54.55	28887		X	
	NHS1-65A	60	16.43	8701			
	NHS1-65B	80	26.71	14145			
	NHS1-65C	100	46.75	24757		X	
Firestone FT 70C; 205/75R15	[illegible]	60	15.42	8166			
	[illegible]	80	20.78	11004			
	[illegible]	100	39.65	20997		X	
	NHS1-24A	60	15.53	8224			
	NHS1-24B	80	21.78	11534			
	NHS1-24C	100	38.5	20388		X	
Michelin XH4; 205/75/R15	[illegible]	60	16.13	8542			
	[illegible]	80	22.53	11931			
	[illegible]	100	47.19	24990		X	
	NHS1-30A	60	16.54	8759			
	NHS1-30B	80	22.19	11751			
	NHS1-30C	100	45.59	24143		X	
BF Goodrich TA VR4; 205/55R15	[illegible]	60	18.51	9802			
	[illegible]	80	46.05	24386			
	[illegible]	100	56.22	29772		X	X
	NHS1-6A	60	18.84	9977			
	NHS1-6B	80	43.97	23285		X	X
	NHS1-6C	100	48.32	25588		X	X
Goodyear Eagle GT II; 205/55R15	[illegible]	60	16.14	8547			
	[illegible]	80	25.45	13477		X	
	[illegible]	100	49.12	26012		X	
	NHS1-34A	60	16.91	8955			
	NHS1-34B	80	26.41	13986		X	
	NHS1-34C	100	40.31	21347		X	
Michelin Pilot HX; 205/55R15	NHS1-35A	60	16.16	8558			
	NHS1-35B	80	22.14	11724			
	NHS1-35C	100	46.78	24773		X	
	NHS1-36A	60	16.2	8579			
	NHS1-36B	80	29.23	15479		X	
	NHS1-36C	100	41.88	22178		X	
Michelin RF MX4; 205/65R15	[illegible]	60	16.25	8605			
	[illegible]	80	20.33	10766			
	[illegible]	100	39.29	20806		X	
	NHS1-42A	60	17.29	9156			
	NHS1-42B	80	19.86	10517			
	NHS1-42C	100	35.26	18672		X	
Goodyear Eagle GA; 205/65R15	[illegible]	60	15.49	8203			
	[illegible]	80	19.34	10242			
	[illegible]	100	37.34	19774		X	
	NHS1-48A	60	15.56	8240			
	NHS1-48B	80	19.63	10395			
	NHS1-48C	100	39.06	20685		X	

PLUNGER IMPACTS

Firestone FT 70C; 205/65R15	NHS1-53A	60	15.45	8182			
	NHS1-53B	80	19.95	10565			
	NHS1-53C	100	40.77	21590		X	
	NHS1-54A	60	15.46	8187			
	NHS1-54B	80	19.16	10146			
	NHS1-54C	100	38.48	20377		X	
Dunlop SP Sport 4000; 205/65R15	[redacted]	60	15.74	8335			
	[redacted]	80	19.93	10554			
	[redacted]	100	34.58	18312		X	
	NHS1-60A	60	16.7	8844			
	NHS1-60B	80	19.98	10581			
	NHS1-60C	100	40.45	21421		X	
BF Goodrich TA TR4; 205/65R15	NHS1-66A	60	15.4	8155			
	NHS1-66B	80	19.66	10411			
	NHS1-66C	100	37.56	19890		X	
	NHS1-67A	60	15.3	8102			
	NHS1-67B	80	19.38	10263			
	NHS1-67C	100	33.22	17592		X	
Firestone FT 70C; 205/75R15	NHS1-68A	60	15.58	8251			
	NHS1-68B	80	19.46	10305			
	NHS1-68C	100	26.17	13859		X	
	NHS1-69A	60	15.23	8065			
	NHS1-69B	80	19.5	10326			
	NHS1-69C	100	27.9	14775		X	
Michelin XH4; 205/75R15	NHS1-70A	60	15.89	8415			
	NHS1-70B	80	20.39	10798			
	NHS1-70C	100	26.78	14182		X	
	NHS1-71A	60	15.94	8441			
	NHS1-71B	80	20.43	10819			
	NHS1-71C	100	24.14	12784			
BF Goodrich TA VR4; 205/55R15	NHS1-31A	60	16.37	8669			
	NHS1-31B	80	29.02	15368		X	
	NHS1-31C	100	40.05	21209		X	
	NHS1-32A	60	16.12	8536			
	NHS1-32B	80	29.64	15696		X	
	NHS1-32C	100	50.65	26822		X	

[redacted] High Speed Performance tested after strength test

To assess repeatability of the J1981 test procedure, two tires of each tire brand/size were run at three different drop angles, totaling three tests per tire, six tests per tire brand/size. For instance, tests NHS1-64A-C were 60/80/100 degree impacts with to one BF Goodrich tire, and tests NHS1-65A-C were 60/80/100 degree impacts to a duplicate BF Goodrich Tire.

In tests with the wedge striker, rim bending and/or contact occurred in some tests where the striker was released from a drop angle of 80 degrees, and all tests where the striker was released from a drop angle of 100 degrees. In tests with the plunger striker, no rim contact was possible due to the impact occurring at the center of the tire tread. However, rubber bottom-out (tire tread pinched between the striker and the center of the wheel) occurred in some tests where the striker was released from a drop angle of 80 degrees, and all tests where the striker was released from 100 degrees. Bottom-out and rim contact (in tests with both wedge and plunger strikers) were usually indicated by sharp peaks in acceleration curves (Figure 4) [1]. In the J1981 tests with the wedge, rim contact was also identified by markings transferred to the sidewall when it folded down and contacted the edge of the rim.

Post-test visual inspection, shearography, and x-rays revealed no damages (i.e. tread, sidewall, ply, or bead separation, chunking, cracking, etc) to any of the tires tested [1].

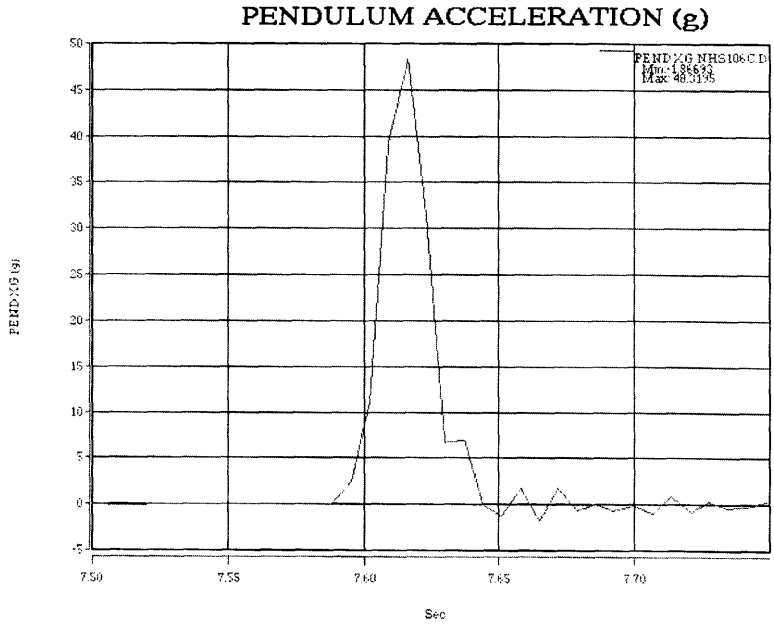

Figure 4: Pendulum Acceleration Curve from a SAE J1981 Test (NHS1-6C) where Rim Contact and Damage Occurred

2.0 CURRENT AND MODIFIED FMVSS 109/119 TIRE STRENGTH TEST

Current and modified FMVSS 109/119 Tire Strength tests were conducted for the purpose of comparing tire damage caused by those tests to damages caused by the original and modified SAE J1981 Road Hazard Impact Tests.

2.1 Test Equipment

The test equipment used to conduct the FMVSS 109/119 Tire Strength tests consisted of a ¾" diameter cylindrical steel plunger with a hemispherical end (FMVSS 109/119 specification) and a wheel mount.

2.2 Test Procedure

Current FMVSS 109/119 Test – Tests were conducted according to the procedures outlined in Section 5.3.2 of FMVSS 109, and Section 7.3 of FMVSS 119.

Modified FMVSS 109/119 Test – Tests were conducted according to the procedures outlined in Section 5.3.2 of FMVSS 109, and Section 7.3 of FMVSS 119, except penetration of tire tread continued until whichever of the following occurred first: an energy 30% higher than what is specified for that tire in the current procedure was reached, or until the tread broke.

2.3 Test Results

Table 2 summarizes the results obtained form the current and modified FMVSS 109/119 Tire Strength tests. To assess repeatability of this procedure, two tires of each tire brand/size were subjected to both tests.

Table 2: Current and Modified FMVSS 109/119 Tire Strength Test Results

Tested Tire Mfg/Brand/Size	Test Number	Current FMVSS 109/119 Plunger Test	Modified FMVSS 109/119 Plunger Test
Michelin RF MX4; 205/65R15	[redacted]	P	
	NHS1-16	P	
	[redacted]		P
	NHS1-38		P
Goodyear Eagle GA; 205/65R15	[redacted]	P	
	NHS1-18	P	
	[redacted]		P
	NHS1-44		P
Firestone FT 70C; 205/65R15	[redacted]	P	
	NHS1-14	P	
	[redacted]		P
	NHS1-50		P
Dunlop SP Sport 4000; 205/65R15	NHS1-19	P	
	NHS1-20	P	
	NHS1-55		P
	NHS1-56		P
BF Goodrich TA TR4; 205/65R15	NHS1-12	P	
	NHS1-61	P	
	NHS1-62		F
	NHS1-63		P

[redacted] High Speed Performance tested after strength test

All tires passed the current plunger test (denoted by a "P" in Table 2), and one tire failed the modified plunger test (denoted by an "F" in Table 2). For that failed tire, the tread broke (resulting in rapid air loss) before reaching the target energy level at three of the five test points. For those three plunger applications, the tread breaks occurred at energy levels 11%, 27%, and 29% above the current FMVSS 109 measurement for that tire (294 Joules, 2600 in-lb). Post-test visual inspection, x-rays, and shearography revealed no damages to any of the tires that passed, and visual inspection revealed a break in the tread on the tire that failed [1].

3.0 FMVSS 109/119 HIGH SPEED PERFORMANCE TEST

A subset of twenty tires that were tested using the current and modified SAE J1981 and FMVSS 109/119 procedures were tested with the current FMVSS 109/119 High Speed Performance test (Table 1 and Table 2). The purpose of the high speed test was to reveal and/or worsen any damages that may have occurred in previous strength tests. In the event that this test would reveal or produce additional damages, it would be considered for inclusion as part of the tire strength test evaluation. All tires subjected to the FMVSS 109/119 High Speed Tests were subsequently visually inspected, x-rayed, and shearographed for damages.

3.1 Test Equipment

The test machine used met specifications outlined in Section 5.5 of FMVSS 109, and Section 7.4 of FMVSS 119.

3.2 Test Procedure

Tests were conducted according to the procedures outlined in Section 5.5 of FMVSS 109, and Section 7.4 of FMVSS 119.

3.3 Test Results

Post-test visual inspection, shearography, and x-ray revealed that the current FMVSS 109/119 High Speed Performance test did not cause any additional damage to any of the tires tested [1].

4.0 SUMMARY AND DISCUSSION OF RESULTS

None of the tires tested with the SAE J1981 Road Hazard Impact machine and wedge-shaped striker had air loss or tire damages detectable by visual inspection, x-ray, or shearography. Impacts to four tires (out of 20) produced minor rim damage when a drop angle of 100 degrees was used. Two of these also showed rim damage with a drop angle of 80 degrees. While this suggests that moderate to severe rim damage would have to occur before any tire damage or air loss could be produced, it is premature to make that conclusion based on these data. The reasons for this are that most of the tires were not tested to the point of rim damage and that a very limited selection of different tires was used.

None of the tires tested with the Road Hazard Impact machine and plunger-shaped striker had air loss or tire damages detectable by visual inspection, x-ray, or shearography. Due to the nature of this test, no rim damage was evident in any of these tests, although there was evidence of rubber bottom-out in some of the tests performed with a drop angle of 80 degrees and in all of those with a drop angle of 100 degrees.

None of the tires tested following the procedures of the current FMVSS 109/119 Tire Strength test had air loss or tire damages detectable by visual inspection, x-ray, or shearography.

One of the tires tested following the procedures of the modified FMVSS 109/119 Tire Strength test had tire damage, which resulted in rapid air loss. None of the other tires had any damage detectable by visual inspection, x-ray, or shearography.

None of the tires tested following the procedures of the current FMVSS 109/119 High Speed Performance test had air loss or tire damages detectable by visual inspection, x-ray, or shearography. Each of these tires had previously been subjected to one of the four road hazard or tire strength tests discussed in this report.

Only one of the 60 tires tested in Phase 1A of this program had air loss or damages detectable by visual inspection, x-ray, or shearography. The research will be expanded in Phase 1B of this

program to include testing of a larger variety of tire sizes, and to include the testing of variations to the above procedures. This is expected to include some testing using the newly proposed procedures for tire endurance.

5.0 REFERENCES

[1] *NHTSA DTNH22-01-P-08475,* STL Technical Report on Phase 1A Laboratory Tire Strength Testing, December 2001, Standards Testing Laboratories, Massilon, Ohio, USA.

[2] *Road Hazard Impact Test for Wheel and Tire Assemblies (Passenger Car, Light Truck, and Multipurpose Vehicles)*, SAE J1981 technical standard, June 1994, Society of Automotive Engineers, Inc., Warrendale, Pennsylvania, USA.

[3] *The Road Hazard Impact Machine*, STL brochure, 1998, Standards Testing Laboratories, Massillon, Ohio, USA.